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Explicit IMF By-dependence in high-latitude geomagnetic activity

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Solar wind-magnetosphere coupling

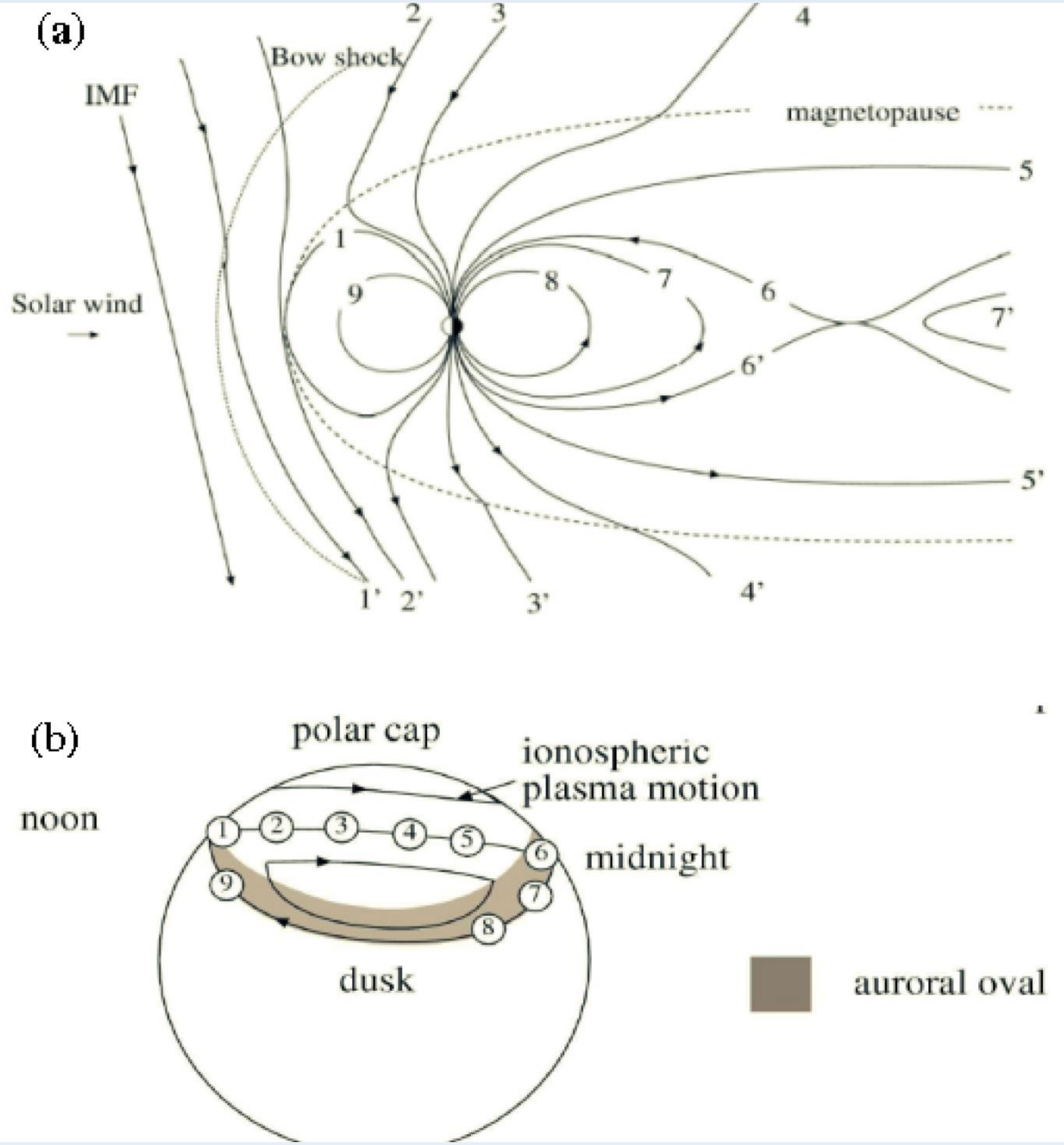
- IMF B_z-component is the main driver of magnetic reconnection at the magnetopause
- IMF B_y is included in coupling functions like the Newell coupling function, but its effect does not depend on its sign

$$\frac{d\Phi_{MP}}{dt} = v^{4/3} B_T^{2/3} \sin\left(\frac{\theta}{2}\right)^{8/3},$$

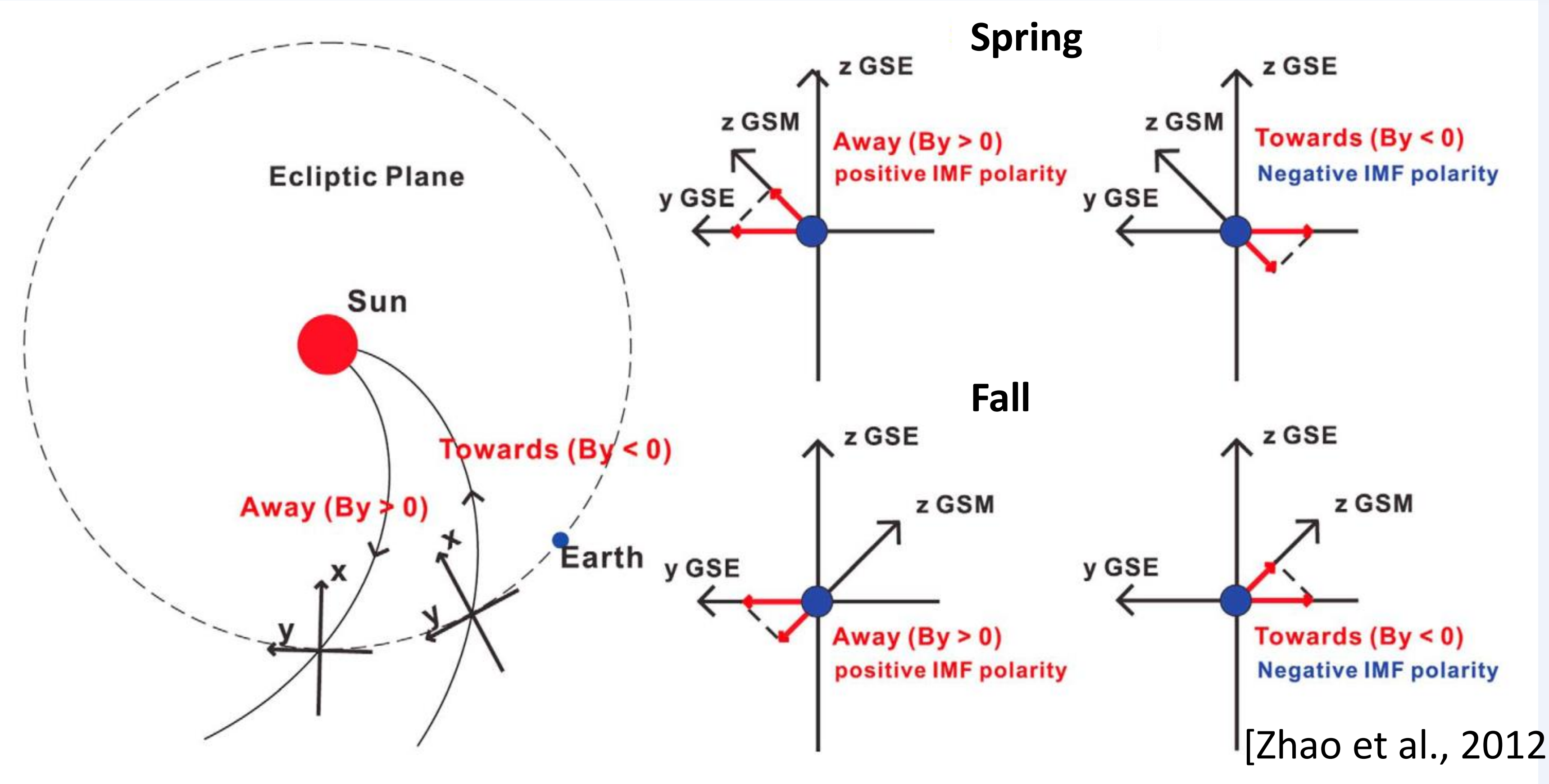
$$B_T = \sqrt{B_z^2 + B_y^2}$$

$$\theta = \arctan\left(\frac{B_y}{B_z}\right)$$

- **Stronger auroral electrojets for B_y>0 than for B_y < 0 in winter!** [Friis-Christensen et al., 2017; Smith et al., 2017]
- **This talk: quantifying the "B_y-effect" using geomagnetic indices**



Russell-McPherron effect

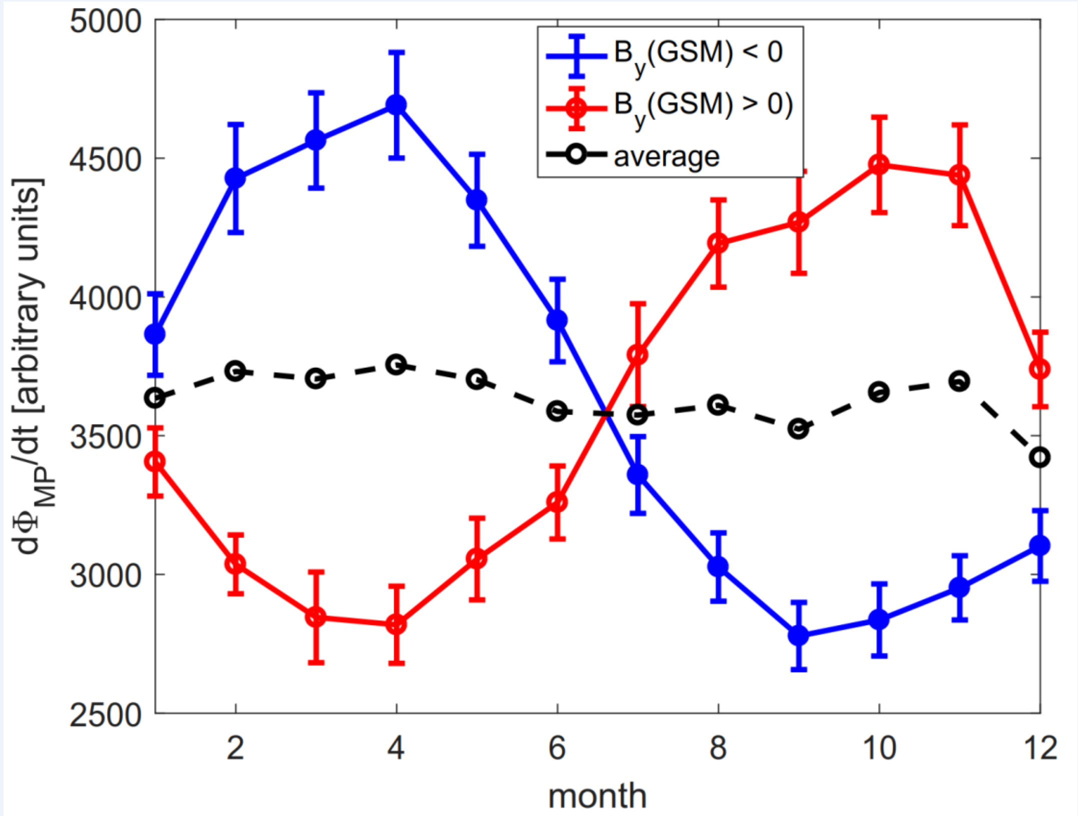


[Zhao et al., 2012]

- IMF B_z and B_y are not statistically independent
- Negative IMF B_z in GSM coordinate system for IMF $B_y > 0$ in fall and for $B_y < 0$ in spring.

Russell-McPherron effect

- Solar wind driving of the magnetosphere is enhanced for IMF $B_y > 0$ in fall, and for $B_y < 0$ in spring.



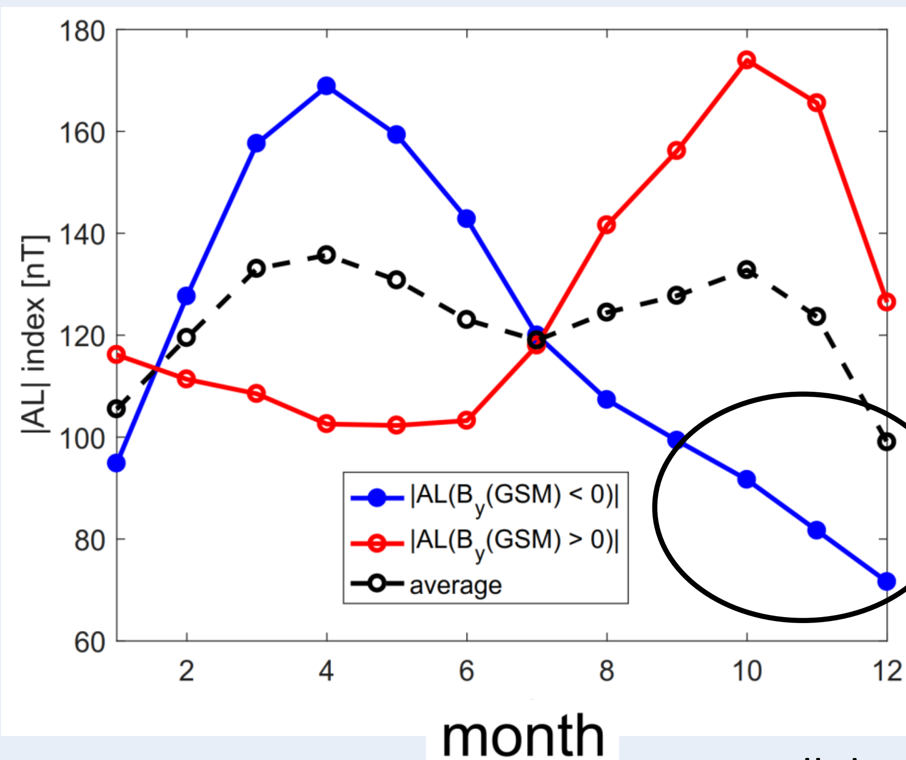
Superposed monthly means and standard errors of the Newell universal coupling function $d\Phi_{MP}/dt$ in 1966-2015

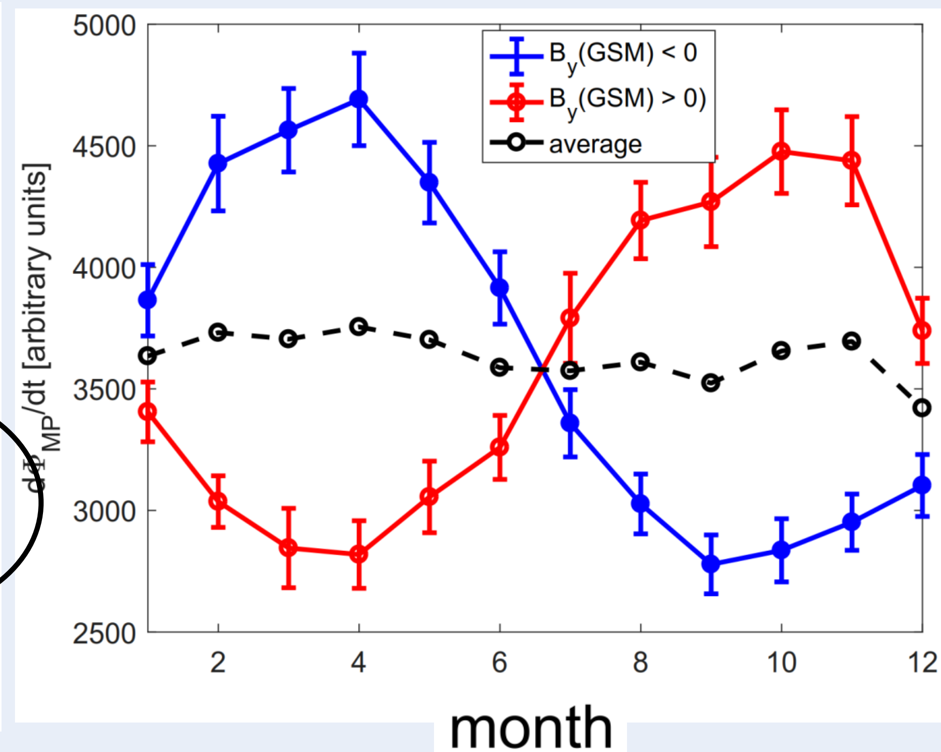
Seasonal variation of AL index

- Deep minimum in AL index during winter for $B_y < 0$

- **Cannot** be explained by the Russell-McPherron effect.

=> Explicit B_y-effect

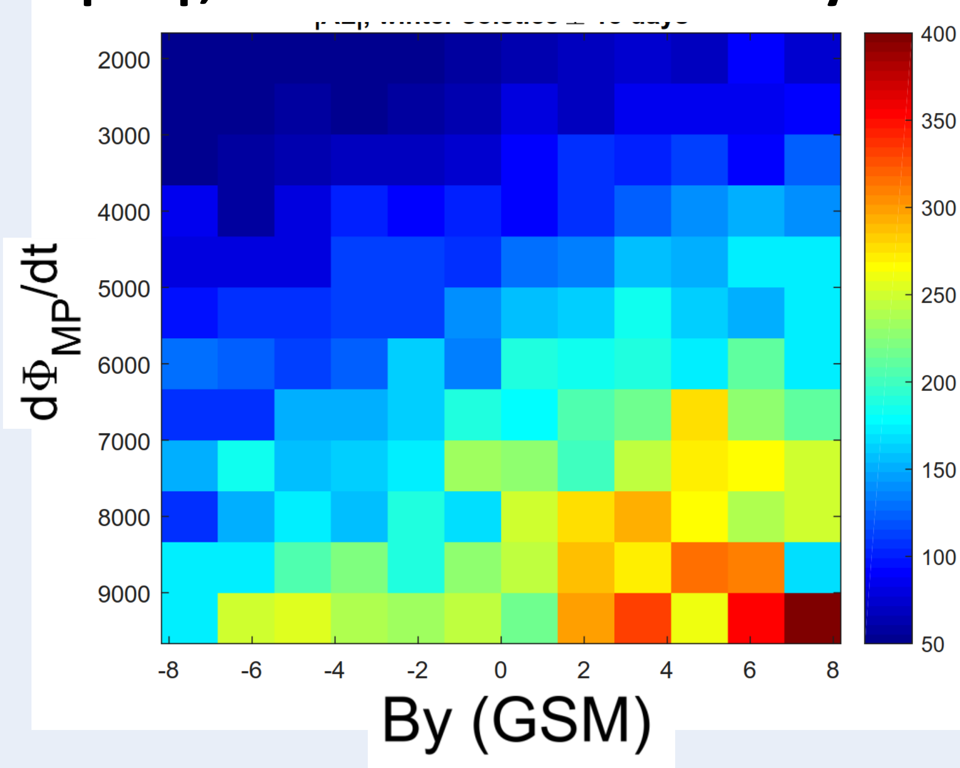




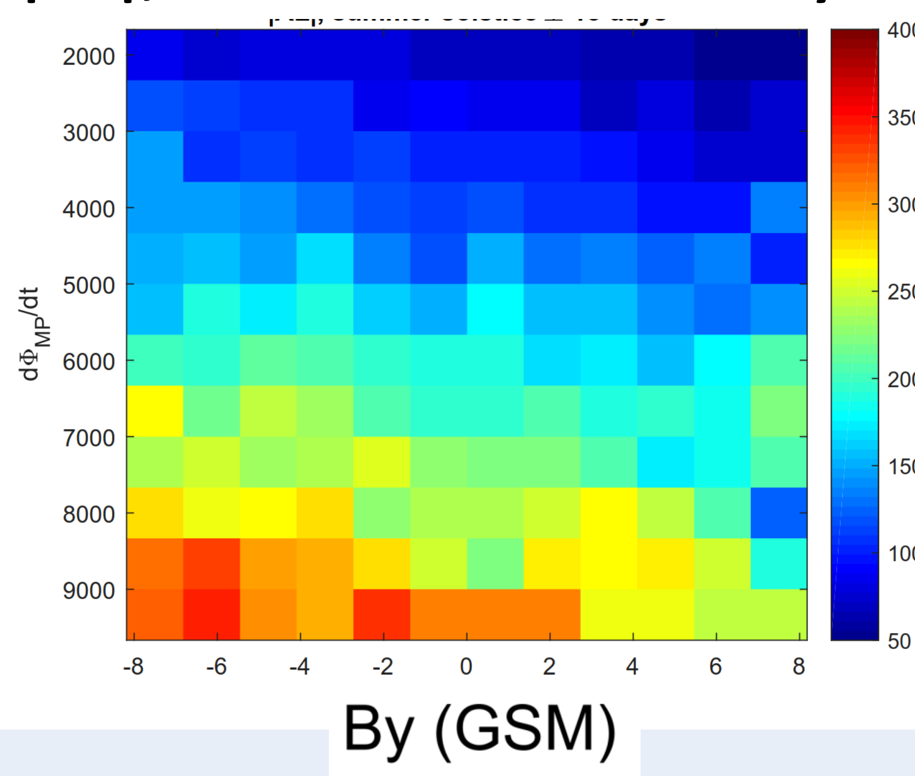
All data in 1966-2015

Explicit B_y-effect in AL index

|AL|, winter solstice ± 15 days



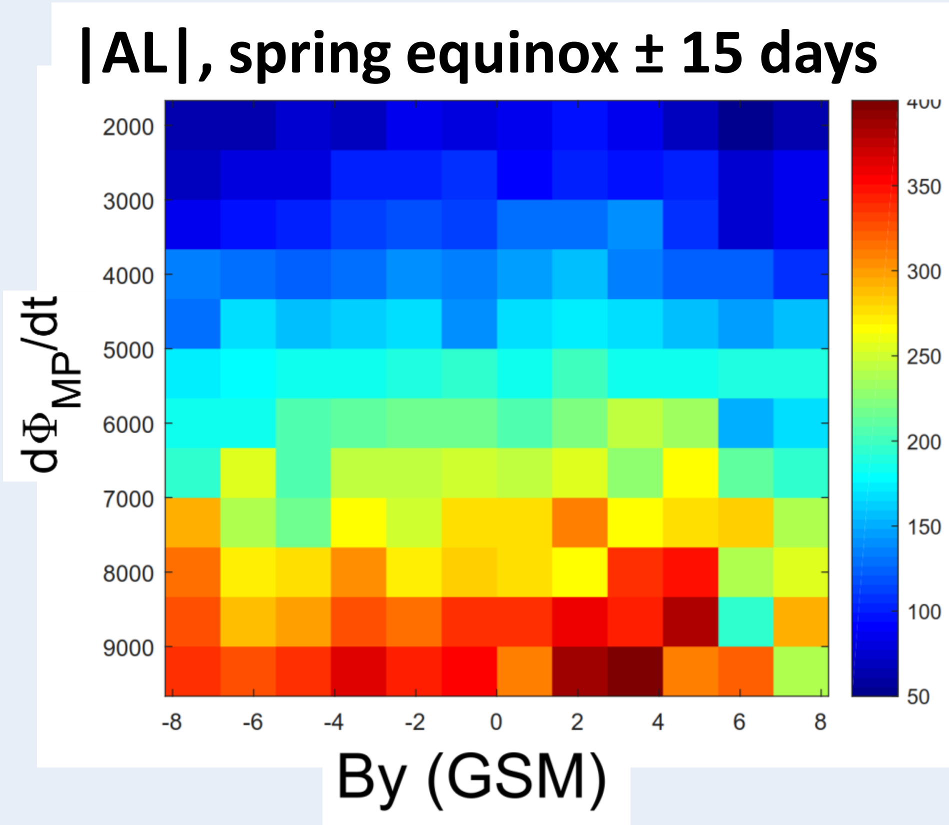
|AL|, summer solstice ± 15 days

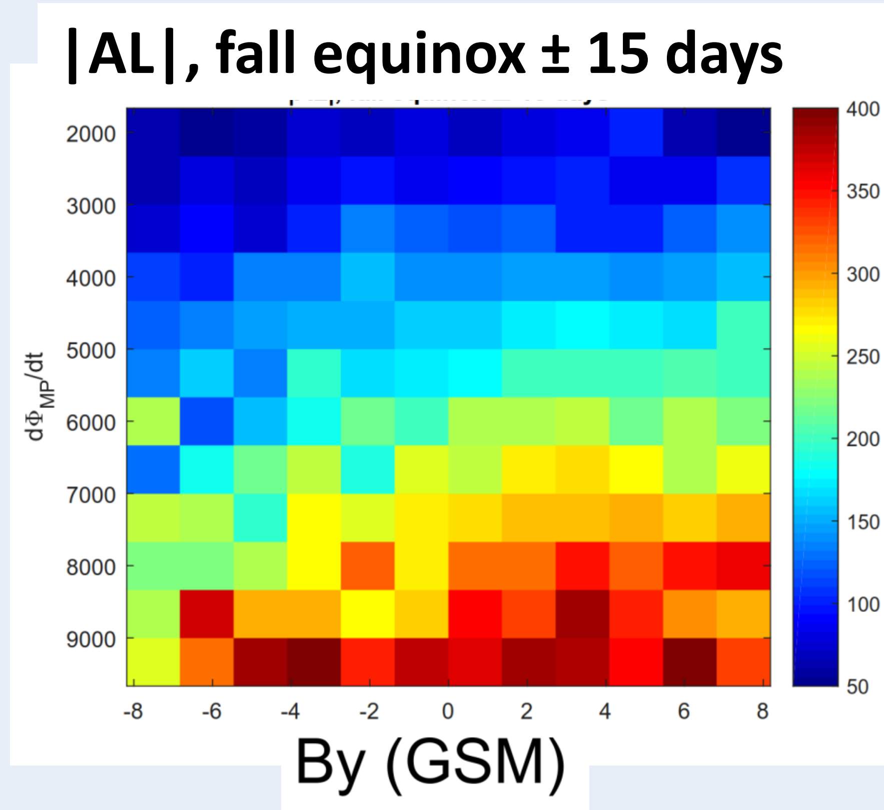


- In NH winter, for the same value of $d\Phi_{MP}/dt$, $B_y > 0$ produces a stronger AL-index than $B_y < 0$.

- Opposite B_y-dependence in NH summer

Explicit B_y-effect in AL index





- Explicit B_y-dependence is very weak around spring and fall equinoxes.

Removing Russell-McPherron effect

a) We calculate measured and predicted ratios

$$R^{+/-}_{meas}(AL) = \frac{|AL(B_y > 0)|}{|AL(B_y < 0)|}$$

$$R^{+/-}_{pred}(AL) = \frac{a \cdot d\Phi_{MP}/dt(B_y > 0) + b}{a \cdot d\Phi_{MP}/dt(B_y < 0) + b},$$

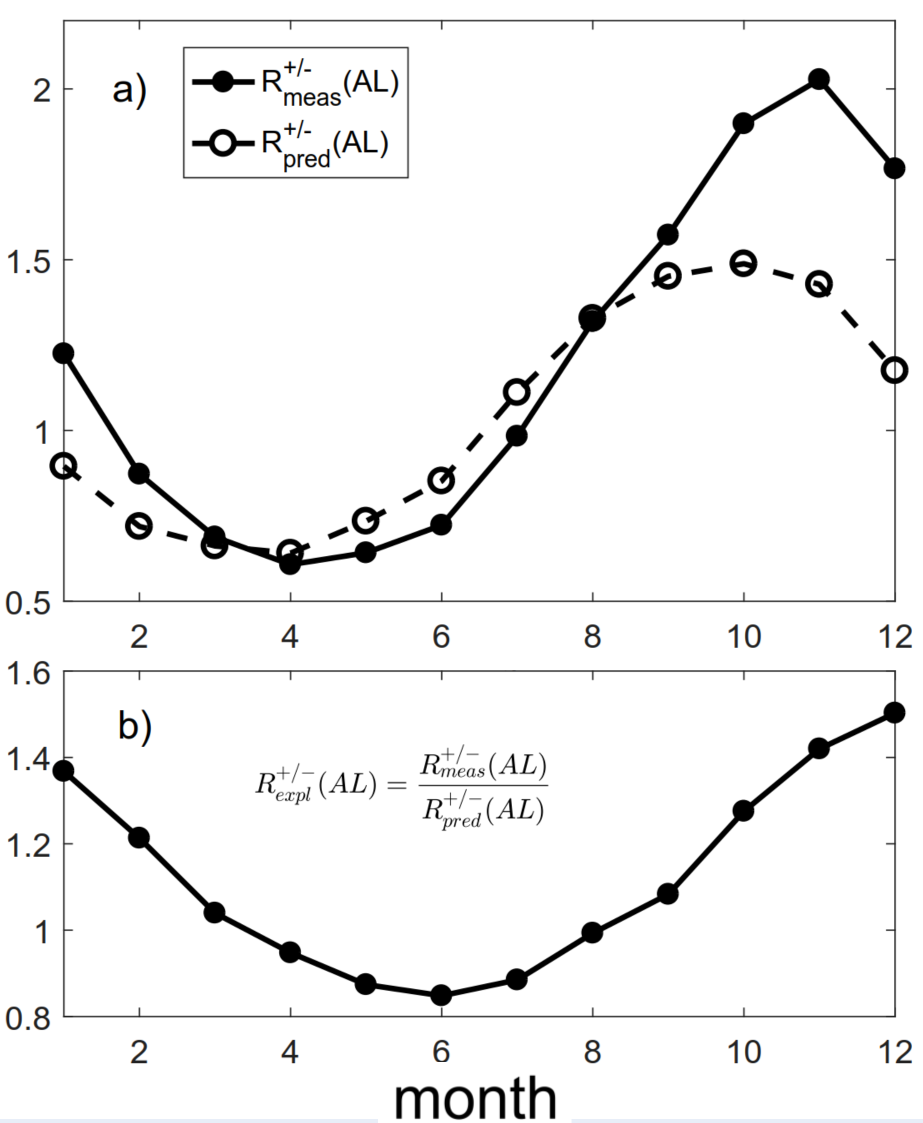
includes only the RMP-effect

b) The ratio of these two ratios

$$R^{+/-}_{expl}(AL) = \frac{R^{+/-}_{meas}(AL)}{R^{+/-}_{pred}(AL)}$$

quantifies the **explicit** B_y-effect

AL index is about **40-50% stronger for B_y>0 than for B_y<0** around the winter solstice.



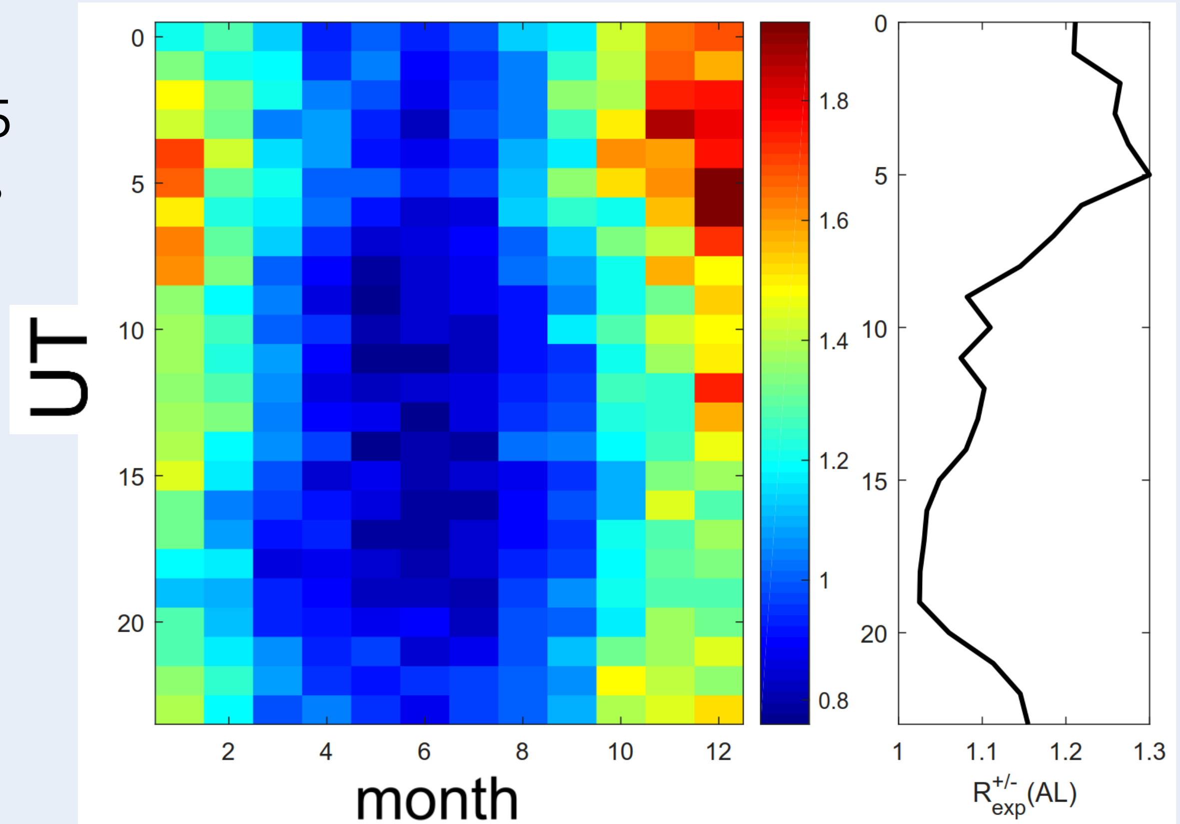
[Holappa and Mursula, *JGR*, 2018]

UT-variation

- The explicit B_y-effect (in NH) maximizes around 5 UT, i.e., when the Earth's dipole axis points away from the Sun

⇒ The explicit B_y-effect maximizes when the auroral region is maximally in darkness

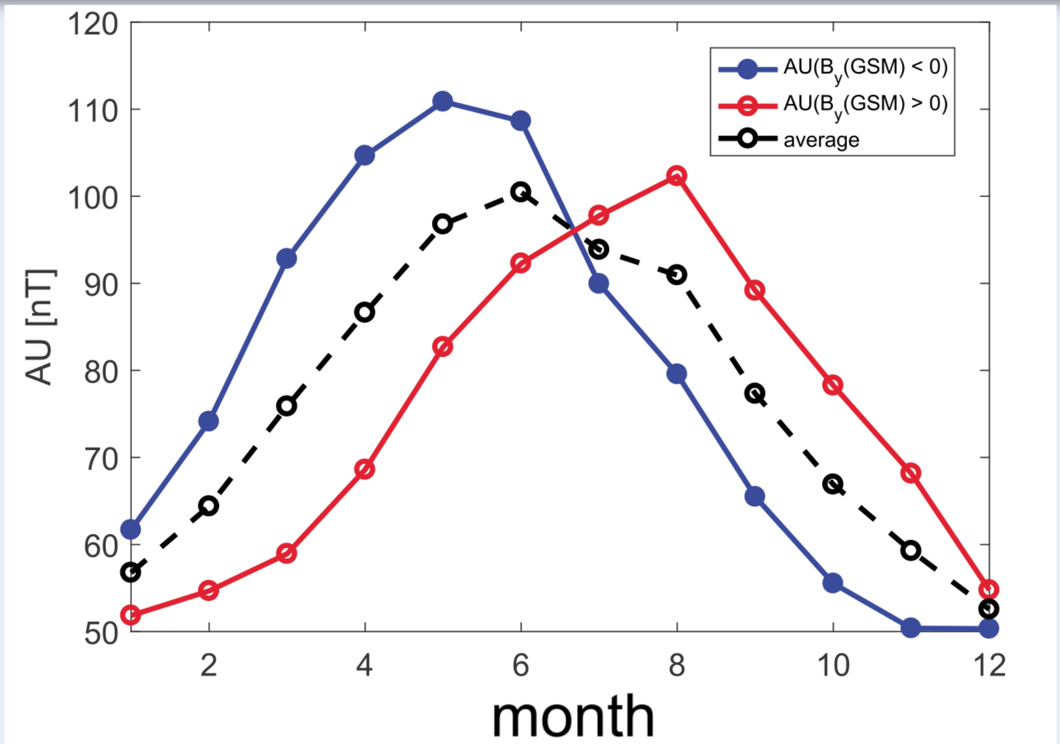
⇒ B_y-effect is efficient under low ionospheric conductivity?

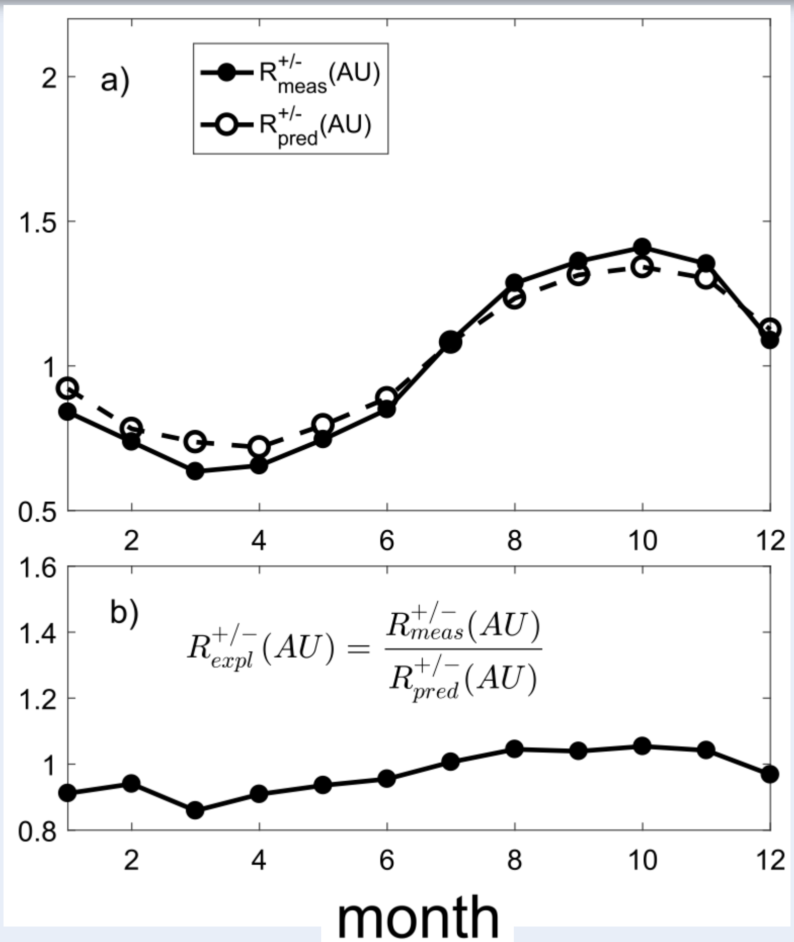


Left: Ratio $R^{+/-}_{expl}$(AL) for different UT hours and months.

Right: $R^{+/-}_{expl}$(AL) averaged over months.

No explicit B_y-effect in AU index





- B_y-dependence in the AU index (eastward electrojet) is solely due to Russell-McPherron effect

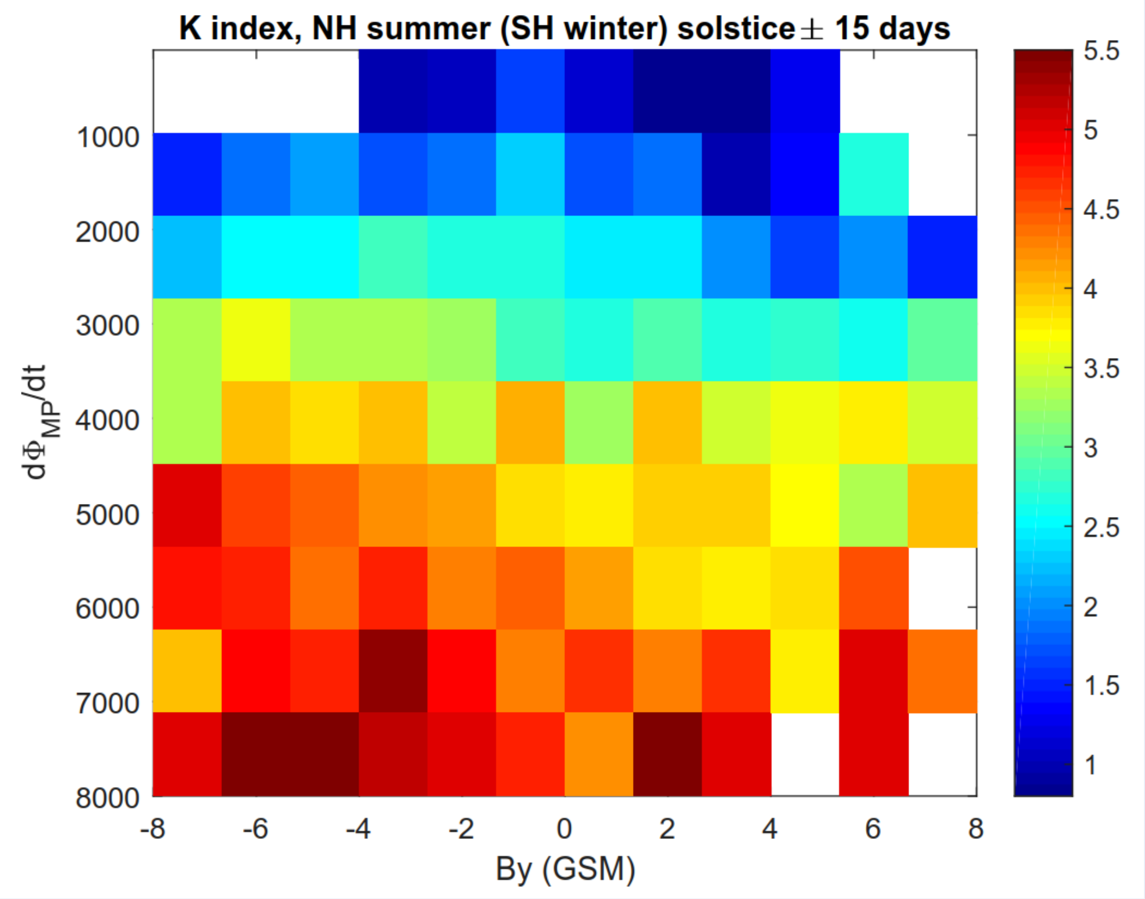
Summary

- IMF B_y is an **explicit** driver of high-latitude geomagnetic activity
- Geomagnetic activity is **significantly stronger for $B_y > 0$** than for **$B_y < 0$** in winter
- B_y-effect maximizes at the winter solstice at 5 UT
- B_y affects the westward electrojet but not the eastward electrojet

- IMF B_y is important for space weather predictions
- **No physical explanation yet!**

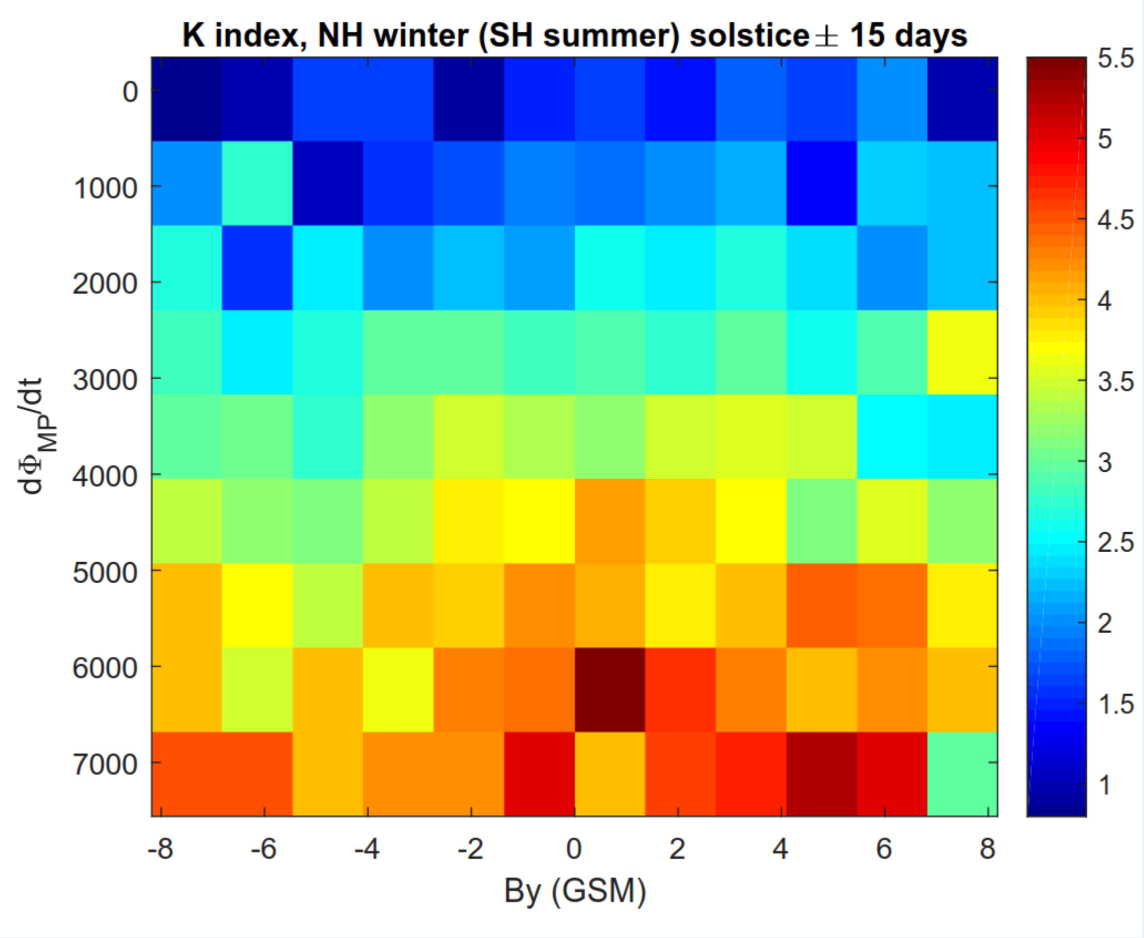
B_y-effect in Southern Hemisphere

- K-index of Syowa station in Antarctica
- During SH winter, for the same value of $d\Phi_{MP}/dt$, $B_y < 0$ produces stronger K-index than $B_y > 0$.
- B_y-dependence in SH is **opposite** to that in NH



B_y-effect in Southern Hemisphere

- During SH summer, for the same value of $d\Phi_{MP}/dt$, $B_y > 0$ produces stronger K-index than $B_y < 0$.



No explicit B_x effect

- There is a correlation between B_y and B_x. Which of the two components is the driver?
- Limiting the amplitude of B_x has almost no effect to the results

=> B_x has only little, if any, explicit effect on high latitude geomagnetic activity